Environment and Natural Resources Trust Fund

2025 Request for Proposal

General Information

Proposal ID: 2025-278

Proposal Title: Recovering Salts from Highly Saline Wastewater

Project Manager Information

Name: Natasha Wright

Organization: U of MN - College of Science and Engineering

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Project Basic Information

Project Summary: We aim to develop a method of recovering useful salts from concentrated saline waste, increasing the economic sustainability of high water-recovery softening, sulfate removal, and industrial wastewater treatment.

ENRTF Funds Requested: $272,000

Proposed Project Completion: June 30, 2028

LCCMR Funding Category: Water Resources (B)

Project Location

What is the best scale for describing where your work will take place?

Statewide

What is the best scale to describe the area impacted by your work?

Statewide

When will the work impact occur?

In the Future

Narrative

Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.

Levels of chloride and sulfate (both salts) in Minnesota waterways is a concern due to the potential for harm to aquatic life (chloride) and the quality of water used for growing wild rice (sulfate). These impacts are the result of linear systems in which resources are extracted, used, and disposed of as waste.

Increased chloride comes from sources including the salt used for winter road maintenance, water softeners, industry, and agriculture. Sulfate also has multiple sources to surface water, including industrial and domestic waste, and use of groundwater for agricultural, industrial, and domestic needs. Because water treatment plants are not equipped with the technology to remove dissolved salts, chloride and sulfate entering these facilities discharge to waterways.

An opportunity exists to reduce this discharge to waterways by installing advanced water treatment technology (such as reverse osmosis, RO). Doing so, however, would result in a liquid waste stream (brine) that contains all the removed contaminants in highly concentrated form. Treating and disposing of this brine is expensive. An ENTRF-funded report indicates that brine management would represent >46% of the total capital cost and >81% of the operational cost of newly installed RO systems at sample sites (MPCA, 2018).

What is your proposed solution to the problem or opportunity discussed above? Introduce us to the work you are seeking funding to do. You will be asked to expand on this proposed solution in Activities & Milestones.

Existing brine management systems are linear; they do not consider the potential useful recovery and reuse of the original salt inputs. We propose to push this linear system to become a circular system, one that aims to keep resources in use for as long as possible, minimizing waste and degradation of the environment.

Our previous ENTRF-funded project explored the use of convection enhanced evaporation (CEE) to reduce the capital and energetic cost of brine management in Minnesota. The system uses packed surfaces to increase the evaporative surface area for a given area of land by >50x. We have modeled and experimentally validated the evaporative performance of the CEE system. As water evaporates from the surfaces, the remaining brine becomes “supersaturated” increasing the tendency of salts to crystallize. This has historically been viewed as a maintenance problem that leads to expensive chemical clean-in-place procedures, but what if this didn’t have to be the case? In this proposal, we expand on our previous work to consider the intentional crystallization of salts when and where we want them to crystallize, for the purpose of useful recovery.

What are the specific project outcomes as they relate to the public purpose of protection, conservation, preservation, and enhancement of the state’s natural resources?

In this proposal, we aim to understand salt crystallization in mixed-salt brines as the next step in achieving our long-term objective of sustainable, circular, systems for managing brine from industrial sources and advanced water treatment plants. This could allow for: (i) reduced discharge of salts to the environment, (ii) on-site recovery of salts for reuse, and (iii) reduced concentration of sparingly soluble salts in the primary water treatment train (e.g. RO), enabling higher water recovery. All three of these potential outcomes would serve to reduce the extraction of water and/or salts, and move Minnesota toward a circular economy.

Activities and Milestones

Activity 1: Develop and validate a model that couples the behavior of salt crystallization with that of concentrating saline water.

Activity Budget: $129,946

Activity Description:
The extent of crystallization for a specific salt mixture depends on both thermodynamic behavior (e.g. saturation indices at a specific temperature) and kinetic behavior (e.g. nucleation rate and crystal growth at a specific time). In on-going work, our team is developing and validating a model that couples these temperature- and time-dependent behaviors of crystallization for relevant salts (e.g. CaSO4 / gypsum, CaCO3 / calcite), at static temperatures and concentrations. As water is removed from brine in a concentrator, however, the remaining brine becomes even saltier, increasing the tendency of salts to crystallize.

In this activity, we aim to couple the temperature- and time-dependent crystallization model currently being developed in the lab with our existing models for brine concentration, to predict the rate of salt crystallization in brine reduction technologies. To validate the integrated model, we will conduct bench-top experiments in which we precisely control the rate of brine concentration, for example using vacuum pumps, in a Stage 1 "Concentrator;" and then pass the brine to a Stage 2 "Crystallizer" where the salts will be allowed to crystalize. The system will operate in a batch mode such that brine leaving the Crystallizer will return to the Concentrator for further processing.

Activity Milestones:

Description	Approximate Completion Date
Crystallization model coupled with existing concentration model (e.g. CEE, membrane).	June 30, 2026
Experimental validation of crystallization model assuming homogeneous nucleation and crystal growth (without a surface).	December 31, 2026
Experimental validation of crystallization model assuming heterogeneous nucleation and crystal growth (with a surface present).	June 30, 2027

Activity 2: Demonstrate the proposed two-stage concentration-crystallization system using commercially available concentration technology.

Activity Budget: $142,054

Activity Description:
We will extend the work in Activity 1 to accommodate commercially available, off-the-shelf, brine concentration technology. In order to do so, we will first work to understand the relative benefit of the proposed two-stage technique for membrane distillation (MD), convection-enhanced evaporation (CEE), and electrodialysis (ED) technologies. All three of these technologies have been used in the "real world" for brine concentration but currently reach practical limits regarding their ability to handle crystallization on the relevant surface (i.e., membranes in the case of MD and ED, evaporation tray in the case of CEE). Based on the initial feasibility study of Activity 1, and the predicted ideal residence time in the Stage 1 Concentrator and Stage 2 Crystallizer, one of the three technologies will be selected as the ideal candidate for further testing and refinement of the process. A bench-scale setup will be constructed for the chosen technology. We will filter and analyze the formed crystals in terms of their composition and size. The crystal mass formed on the substrate will be compared with the modeled results.

Activity Milestones:

Description	Approximate Completion Date
Conceptual framework developed for two-stage concentrator + crystallizer system and most viable technology option selected.	September 30, 2027
Construction of bench-scale two-stage concentrator + crystallizer system.	December 31, 2027
Experimental results from two-stage concentrator + crystallizer system summarized and compared to modeled predictions.	March 31, 2028
Findings summarized with initial assessment of real world application for the proposed concentrator-crystallizer configuration.	June 30, 2028

Long-Term Implementation and Funding

Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this work be funded?
We will pursue National-scale funding for this project through the Bureau of Reclamation, a federal agency particularly interested in saline brine management. This agency has previously supported our field testing of convection enhanced evaporation (CEE) systems and is currently supporting our fundamental work on crystallization kinetics. We also hope to work with a team at the Carlson School of Management to determine realistic value propositions for the technology.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Managing Highly Saline Waste From Municipal Water Treatment	M.L. 2021, First Special Session, Chp. 6, Art. 5, Sec. 2, Subd. 04a	$250,000

Project Manager and Organization Qualifications

Project Manager Name: Natasha Wright

Job Title: Assistant Professor of Mechanical Engineering

Provide description of the project manager's qualifications to manage the proposed project.
B.S., Mechanical Engineering, 2012, University of St. Thomas, St. Paul, MN
S.M., Mechanical Engineering, 2014, Massachusetts Institute of Technology, Cambridge, MA
PhD, Mechanical Engineering, 2018, Massachusetts Institute of Technology, Cambridge, MA
Post-Doctoral Associate, Environmental Engineering, 2019, University of Minnesota

Dr. Natasha Wright will be responsible for the overall project coordination. Her research focuses on the design of decentralized energy-water systems, with a specialty in thermal and membrane-based separation processes (including desalination for salt removal) and their pairing with renewable energy sources. Over the last 10 years, she has piloted combined energy generation + water treatment systems in the United States, India, and Gaza. Recent work has focused on reducing the cost of small-scale desalination systems via the redesign of system sub-components. This work has resulted in numerous design awards including Forbes 30 Under 30 and the Lemelson Prize at MIT, three patents, and several papers in the field of Desalination. She will complete an LCCMR-supported project in June 2024 which aims to characterize and optimize convection-enhanced evaporation systems for MN climatic conditions. That project has led to one granted patent and four journal publications.

Organization: U of MN - College of Science and Engineering

Organization Description:
The University of Minnesota is one of the largest, most comprehensive, and most prestigious public universities in the United States (https://twin-cities.umn.edu/about-us). The laboratories and offices of the PI, along with UMN characterization facilities, contain all of the necessary fixed and moveable equipment and facilities needed for the proposed studies.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Project Manager		Project coordination, guide development of model extension, supervise graduate student. 1 month/year, 3 years, including UMN rate of 37.1% benefits.			27.1%	0.24		$51,705
Graduate Research Assistant		Analytical model extension, experimental testing, data synthesis. Includes UMN rate of 25.1% benefits plus tuition.			25.1%	1.5		$183,155
Undergraduate Researcher		Assist with experimental data collection. 1 students for 5 hours/wk at $16/hr over 2 years.			0%	0.24		$8,320
							Sub Total	**$243,180**
Contracts and Services								
							Sub Total	**-**
Equipment, Tools, and Supplies								
	Tools and Supplies	Prototyping materials, consumable supplies, sensors and data acquisition equipment, scientific characterization facilities use fees, operating costs for laboratory instruments required for analyses and experiments	Tools and supplies required to experimentally validate the salt crystallization models.					$20,820
							Sub Total	**$20,820**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								

							Sub Total	**-**
Travel Outside Minnesota								
	Conference Registration Miles/ Meals/ Lodging	2 people (program manager and graduate student); flight, 3 nights hotel, conference registration.	Formal presentation of project findings.	X				$3,000
							Sub Total	**$3,000**
Printing and Publication								
	Publication	Publications charges (x2)	To make published journal articles immediately available via open access to maximize data availability and dissemination.					$5,000
							Sub Total	**$5,000**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$272,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
Travel Outside Minnesota	Conference Registration Miles/Meals/Lodging	2 people (program manager and graduate student); flight, 3 nights hotel, conference registration.	Attendance at US-based conferenced for formal presentation of project findings.

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	**-**
Non-State				
In-Kind	University of Minnesota	Because the project is overhead free, laboratory space, electricity, and other facilities/administrative costs (55% of direct costs excluding permanent equipment and graduate student tuition benefits) are provided in-kind.	Secured	$119,884
			Non State Sub Total	**$119,884**
			Funds Total	**$119,884**

Total Project Cost: $391,884

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: 6030c44d-222.pdf

Alternate Text for Visual Component

The figure shows the difference between linear systems, in which a resources (salt) is used for an industrial process and then discharged to waterways, vs. a circular system, in which the same resource is used and then recovered during the brine treatment step, limiting discharge to waterways....

Supplemental Attachments

Capital Project Questionnaire, Budget Supplements, Support Letter, Photos, Media, Other

Title	File
UMN Letter of Support from Sponsored Projects Administration	1c2b6d9c-d3e.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Does your project have potential for royalties, copyrights, patents, sale of products and assets, or revenue generation?

Yes

Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?

Yes

Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?

No

Does your project include original, hypothesis-driven research?

Yes

Does the organization have a fiscal agent for this project?

No

Does your project include the pre-design, design, construction, or renovation of a building, trail, campground, or other fixed capital asset costing $10,000 or more or large-scale stream or wetland restoration?

No

Do you propose using an appropriation from the Environment and Natural Resources Trust Fund to conduct a project that provides children's services (as defined in Minnesota Statutes section 299C.61 Subd.7 as "the provision of care, treatment, education, training, instruction, or recreation to children")?

No

Provide the name(s) and organization(s) of additional individuals assisting in the completion of this proposal:

N/A